Peripheral Refraction With Toric Orthokeratology and Soft Toric Multifocal Contact Lenses in Myopic Astigmatic Eyes

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Purpose. There has been little research on myopia management options for patients with astigmatism. This study quantified changes in peripheral refraction induced by toric orthokeratology (TOK) and soft toric multifocal (STM) contact lenses.

Methods. Thirty adults with refractive error of plano to −5.00 D (sphere) and −1.25 to −3.50 D (cylinder) were enrolled. Cycloplegic autorefraction was measured centrally, ±20 degrees, and ±30 degrees from the line of sight nasally (N) and temporally (T) on the retina. Measurements were made at baseline, after 10 ± 2 days of TOK wear (without lenses on eye), and after 10 ± 2 days of STM wear (with lenses on the eyes) and compared with repeated-measures analysis of variance.

Results. Compared to baseline, TOK induced a myopic shift in defocus (M) at all locations (all $P < 0.01$), but STM only induced a myopic shift at 20 T in both eyes and 30 N/T in the left eye (all $P < 0.01$). TOK resulted in more myopic defocus than STM at all locations (all $P < 0.05$) except 20 T in the left eye. TOK induced more J_0 astigmatism at all locations (all $P < 0.02$), except 20 N in the right eye; J_0 with STM was different than baseline at 20 N in both eyes and 30 N in the right eye (all $P < 0.02$). TOK induced more J_0 astigmatism than STM at all locations (all $P < 0.01$), except 20 T in the left eye. Differences in J_{45} astigmatism, when significant, were clinically small.

Conclusions. Greater amounts of peripheral myopic defocus and J_0 astigmatism were induced by TOK compared to STM, which may influence efficacy for myopia management.

Keywords: myopia, astigmatism, peripheral refraction, orthokeratology, soft multifocal

Although researchers and clinicians now recognize the myopia pandemic, moderate to high astigmatism that may accompany myopia has been largely ignored in studies involving optical treatment strategies. Astigmatism is twice as prevalent in patients with myopia compared to patients with hyperopia.[1] In the United States, the prevalence of astigmatism among children is approximately 28%.[2] As summarized by Li et al., the prevalence of astigmatism ≥0.75 D is even higher in parts of Asia.[3] The presence of astigmatism, especially higher amounts, can make contact lens fitting more challenging, and thus impact the tolerability and efficacy of contact lens treatment options for myopia management. Patients with astigmatism of more than one diopter (D) have often been excluded from clinical trials[4] due to potential lens decentration,[5] which may cause induced astigmatism,[6,7] and poor visual performance due to uncorrected astigmatism.[8]

The primary accepted theory as to how optical devices slow myopia progression is by imposing myopic defocus in the peripheral retina.[9] Previous studies have demonstrated a significant increase in myopic defocus induced by both orthokeratology and distance-center soft multifocal designs.[10] Researchers have hypothesized that higher amounts of myopic defocus may be more effective in slowing myopia progression.[11] But, to date, no studies have reported the effects of toric orthokeratology or soft toric multifocal contact lenses on peripheral refraction.

The purpose of this study was to quantify changes in peripheral refraction caused by toric orthokeratology (TOK) and soft toric multifocal (STM) contact lens wear to understand their effect and potential impact on eye growth for myopia management.

Methods

The study was a prospective, single site, randomized, crossover study and was registered on clinicaltrials.gov (NCT03728218). This study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board at the University of Houston. Informed consent was obtained from each subject prior to the start of any measurements. The data for this analysis were part of a larger study which aimed to explore subjective and objective outcomes of TOK and STM in myopic astigmatic adults. Outcomes of the higher-order aberrations have been published previously,[12] as have details on the clinical fitting process for TOK.[13]

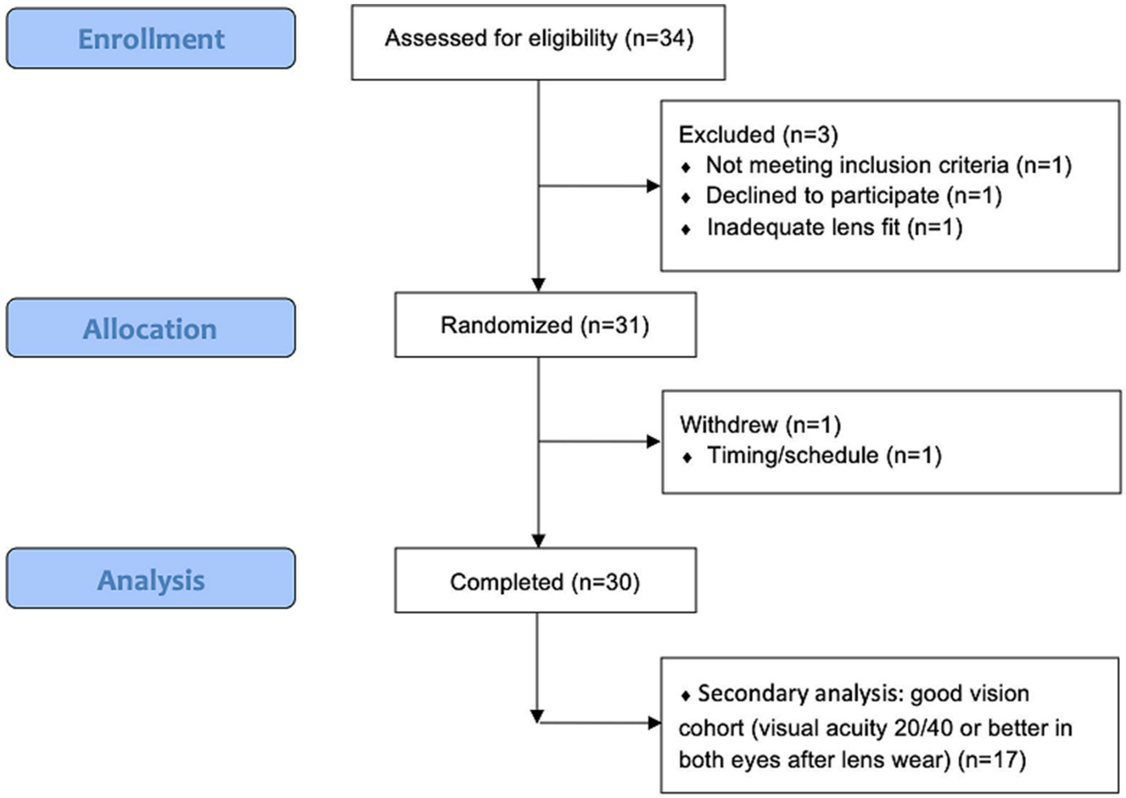

FIGURE 1. Subject recruitment and enrollment.

Subjects

Subjects were non-presbyopic adults (aged 18–39 years) with spherical component of refractive error ranging from plano to −5.00 D and −1.25 to −3.50 D of refractive cylinder, when referenced to the corneal plane. Best corrected visual acuity was 20/25 or better in each eye. Any subjects with a history of ocular pathology or surgery or clinically significant binocular vision disorders were excluded. Additionally, subjects were excluded if they wore gas permeable lenses within 1 month prior to enrollment. A total of 34 subjects were assessed for eligibility, but one failed to meet the inclusion criteria, one did not achieve adequate lens fit with both lenses, and 2 others withdrew due to time commitments, so a total of 30 subjects completed the 5-visit study (Fig. 1).

Contact Lenses

The full fitting protocol was published previously.[12,13] Briefly, the Proclear Multifocal Toric (CooperVision, Pleasanton, CA, USA) center distance +2.50 D add design[14] and Dual Axis Corneal Refractive Therapy (CRT; Paragon Vision Sciences, Gilbert, AZ, USA) lenses were used as they were the most commonly fitted lenses for patients with astigmatism in our Myopia Management Service at the start of the trial. Dual Axis CRT lenses have toric peripheral and alignment curves to improve centration but maintain a spherical base curve. Lenses were ordered empirically based on the manufacturer's guidelines using the subject's manifest refraction, corneal topography, average elevation difference between the vertical and horizontal meridians at an 8-mm chord, and horizontal visible iris diameter. Changes to the lens fit were not made, as there is no agreed-upon standard for re-fitting patients with astigmatism with TOK; however, the subject only continued if the lens fit and distance visual acuity were acceptable (20/40 or better) with both lens types. A secondary outcome of the study was to assess the success rate for empirical lens ordering for patients with astigmatism.

The order of contact lens wear was randomized by a masked study team member using a random number generator. There was a 14 ± 2 day washout period between wearing each lens type, during which subjects wore their habitual correction. A 2-week washout period was deemed acceptable due to previous research,[15] but corneal tomography with the Pentacam HR (Oculus, Wetzlar, Germany) was also performed to ensure proper washout and return to baseline corneal curvature prior to commencing wear with the second set of lenses.

Cycloplegic Autorefraction

Central and peripheral autorefraction were measured with the WAM-5500 (Grand Seiko Co., Hiroshima, Japan) approximately 30 minutes after cycloplegia with 2 drops of 1% tropicamide separated by 5 minutes at baseline and each outcome visit.[16] Subjects viewed a red laser target that was projected on to the wall at least 2.5 meters away. Measurements were taken centrally and ± 20° and ± 30° nasally and temporally on the retina from the line of sight. At least five measurements were taken per location per eye. The 95% limits of agreement for peripheral refraction measures of defocus are ± 0.42 D at 20 degrees and ± 0.60 D at 30 degrees on the retina.[17] For all peripheral measurements, the subject's head was rotated to allow the eyes to remain in primary gaze, to minimize the effect of contact lens decentration due to eye turn.[18,19] If any measurements had a spherical equivalent value that was more than 1 D different, or cylinder power more than 3 D different, than the median of the measurements taken at that the same location and condition, the measurement was excluded from analysis. Only two data points had three or four valid measurements. Otherwise, all subjects, visits, locations, and conditions had five usable measurements. Autorefraction measurements were converted into power vectors of M, J_0, and J_{45} using published formulas[17] and averaged at each location for each eye.

Central and peripheral cycloplegic autorefraction were performed at baseline and at the outcome visits for each lens type (after 10 ± 2 days of wear). At baseline and after TOK lens wear,[20] autorefraction was performed without correction or lenses on the eyes. When the STM lenses were worn, the autorefraction was taken with the lenses on the eyes. For the baseline condition, the subjective manifest refraction was subtracted from the central and peripheral autorefraction. For each lens type, the over-refraction was subtracted from the central and peripheral autorefraction. To accomplish these adjustments, the spherical equivalent of the over-refraction for each lens type was subtracted from the mean defocus (M) measured by the autorefractor at each retinal location with that lens type. The same process was followed to apply the over-refraction to J_0 and J_{45}.

Statistical Analysis

A sample size for the study was based on a primary outcome of a difference of at least 6 letters of visual acuity, which required a sample size of at least 24, based on an $\alpha = 0.05$, $\beta = 0.20$.[21] The study aimed to enroll 30 subjects to allow for up to a 20% dropout or missing data. Post hoc sample size analysis for this study with $\alpha = 0.05$, $\beta = 0.20$, and an effect size of 0.70 would require a sample of 26 participants.

In addition to analyzing the entire sample of 30 participants, a subcohort was established to include only participants who achieved high-contrast logMAR acuity of +0.30 (20/40 Snellen equivalent) or better in each eye with both lens treatments. This is a commonly used cutoff to measure visual acuity success in orthokeratology[22] and refractive surgery.[23] The good vision subcohort allows for comparisons to be made with our published aberration outcomes[12] and is indicative of what would happen in a clinical setting, given that practitioners would often re-fit lenses if the vision was not satisfactory. Data were summarized and demographics reported as means and standard deviations. Peripheral refraction (M, J_0, and J_{45}) were each analyzed using a repeated measures analysis of variance (RM-ANOVA) that included repeated factors of eye (right and left), retinal location (30 degrees nasal, 20 degrees nasal, central, 20 degrees temporal, and 30 degrees temporal), and lens condition (baseline [no lens], TOK, and STM). If the overall RM-ANOVA showed significant differences, Benjamini-Hochberg corrected post hoc paired *t*-tests were performed to correct for multiple comparisons.

Results

Thirty participants completed the study (60 eyes). Based on empirical fitting, 34 eyes of 17 participants met the vision threshold of +0.30 logMAR (Snellen 20/40) or better after 10 ± 2 days of lens wear with both lens types and comprise the good vision subcohort. Of the 13 participants that were excluded, 22 eyes of 12 subjects failed to reach the vision threshold (+0.30 logMAR) with TOK and 3 eyes of 3 subjects with STM. All dispensed lenses were deemed clinically acceptable. STM lenses were stable with a median of 18.5 degrees of rotation (interquartile range [IQR] = 7–30). TOK lenses were adequately centered with good treatment and return zones and edge lift.

The included subjects ($n = 30$, mean ± SD) were 24.7 ± 4.3 years old (range = 19 to 38 years) and 56% ($n = 17$) were women. The photopic pupil size measured by the VIP-300 pupillometer (NeurOptics, Irvine, CA, USA) was 4.42 ± 0.65 mm. Based on manifest refraction, 54 eyes had with-the-rule astigmatism (180 ± 30 degrees), 4 had against-the-rule astigmatism (90 ± 30 degrees), and 2 had oblique astigmatism. Subjects in the good vision cohort were less myopic (0.44 D OD and 0.56 D OS) but had the same amount of astigmatism as the full sample (Table 1).

For defocus (M) and each astigmatism term (J_0 and J_{45}), there were significant interactions involving the eye (right or left), so eyes were analyzed and reported separately. For each refractive component (M, J_0, and J_{45}), there were significant changes that depended on lens condition (all $P < 0.001$).

Defocus

Defocus (M) at each retinal location depended on the lens condition (lens condition × location interaction; $P < 0.01$). Baseline peripheral refraction profiles for right and left eyes were similar with little to no peripheral defocus (Figs. 2A, 2B, blue lines). Compared to baseline peripheral refraction, STM induced peripheral myopic defocus at 20 degrees temporal on the retina in both eyes and 30 degrees nasal and temporal in the left eye (see Fig. 2A green lines, all $P < 0.01$). The results are the same for the good vision cohort (see Fig. 2B green lines, all $P < 0.02$) with the addition of 30 degrees nasal in the right eye ($P < 0.02$). For the full sample, TOK induced myopic defocus at all locations compared to baseline for the full sample (see Fig. 2A red lines, all $P < 0.01$) and good vision cohort (see Fig. 2B red lines, all $P < 0.02$).

Table 1. Baseline Refractive Error of Included Eyes

Baseline Refractive Error	Full Sample ($N = 30$)			Good Vision Cohort ($N = 17$)		Comparison of Full Sample Versus Good Cohort	
(Mean ± SD)	OD	OS	OD vs. OS	OD	OS	OD vs. OS	Average of Eyes
Sphere (D)	−2.73 ± 1.27	−2.62 ± 1.35	$P = 0.33$	−2.29 ± 0.95	−2.06 ± 1.09	$P = 0.09$	$P = 0.02$
Cylinder (D)	−2.00 ± 0.49	−2.03 ± 0.52	$P = 0.70$	−1.94 ± 0.48	−2.04 ± 0.57	$P = 0.40$	$P = 0.74$
Spherical Equivalent (D)	−3.73 ± 1.25	−3.64 ± 1.29	$P = 0.40$	−3.26 ± 0.94	−3.08 ± 1.03	$P = 0.22$	$P = 0.02$

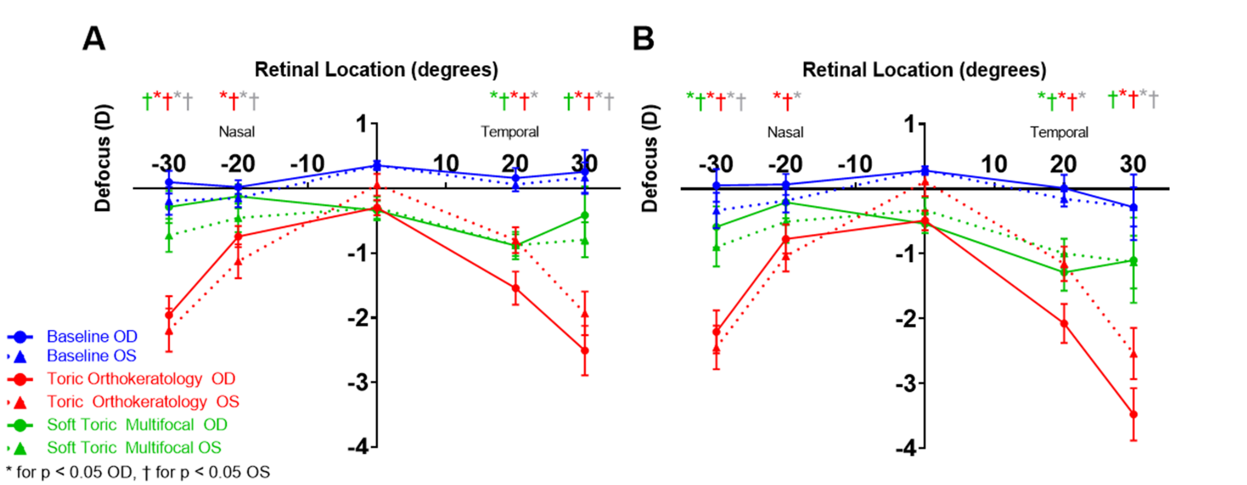

Figure 2. Myopic defocus for the full sample (**A**) and good vision cohort (**B**) showing baseline (*blue*), toric orthokeratology (TOK, *red*), and soft toric multifocal (STM, *green*) conditions for the right (*solid line*) and left (*dashed line*) eyes. * Indicates $P < 0.05$ for the right eye, † Indicates $P < 0.05$ for the left eye when compared to baseline, and appear *gray* when comparing both lens types. Error bars represent standard error of the mean.

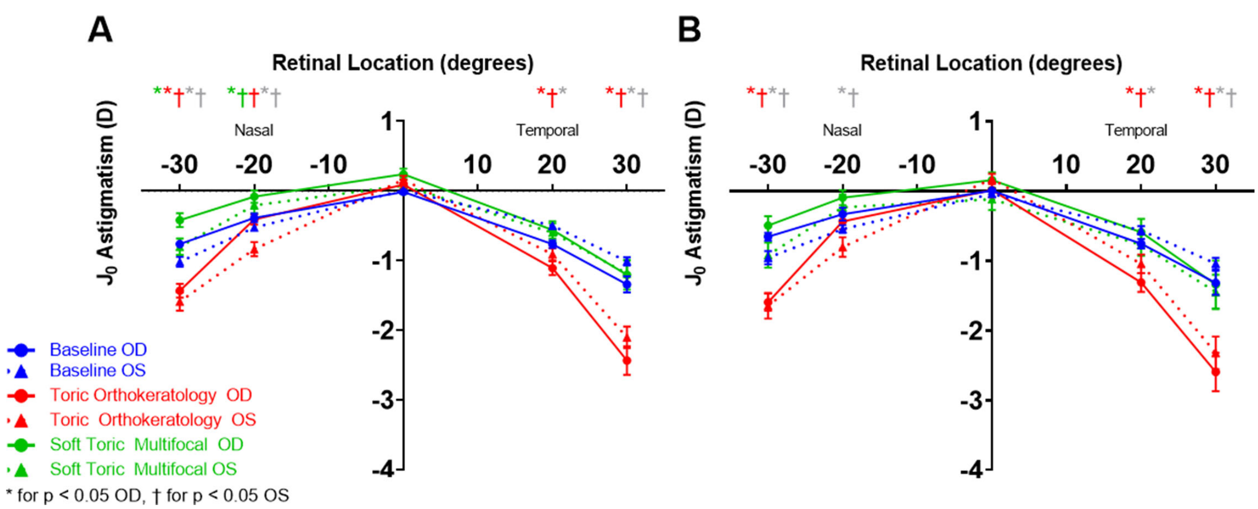

Figure 3. J_0 astigmatism for the full sample (**A**) and good vision cohort (**B**) showing baseline (*blue*), toric orthokeratology (TOK, *red*), and soft toric multifocal (STM, *green*) conditions for the right (*solid line*) and left (*dashed line*) eyes. * Indicates $P < 0.05$ for the right eye. † Indicates $P < 0.05$ for the left eye when compared to baseline, and appear *gray* when comparing both lens types. Error bars represent standard error of the mean.

Finally, comparing the two lens treatments to each other in the full sample, there was greater myopic defocus with TOK at all peripheral locations in both eyes, except 20 degrees temporal in the left eye (see Fig. 2A, all $P < 0.05$). For the good vision cohort, there was greater myopic defocus with TOK at all locations except 20 degrees nasal and temporal in the left eye (see Fig. 2B, all $P < 0.05$).

Astigmatism

J_0 (with/against the rule) astigmatism at each retinal location depended on the lens condition (lens condition × location interaction; $P < 0.01$). For the full sample, STM varied from baseline at 20 degrees nasal in both eyes and 30 degrees nasal in the right eye (Fig. 3A, all $P < 0.02$). There was no difference between STM and baseline for the good vision cohort (Fig. 3B, all $P > 0.05$). TOK induced more J_0 astigmatism than baseline for the full sample at all locations except 20 degrees nasal in the right eye (see Fig. 3A, all $P < 0.02$). Similarly for the good vision cohort, TOK induced more J_0 astigmatism than baseline at all locations except 20 degrees nasal in both eyes (see Fig. 3B, all $P < 0.02$). When comparing the two lens treatments to each other, TOK resulted in more J_0 astigmatism at all locations except 20 degrees temporal for the left eye in both the full sample and good vision cohort (see Fig. 3, all $P < 0.05$).

Finally, J_{45} (oblique) astigmatism at each retinal location in each eye depended on the lens condition (eye × lens condition × location interaction; $P < 0.01$). J_{45} astigmatism varied by eye, but overall was smaller in magnitude compared to sphere (M) and J_0 astigmatism. In the full sample, STM differed from baseline at 30 degrees nasal

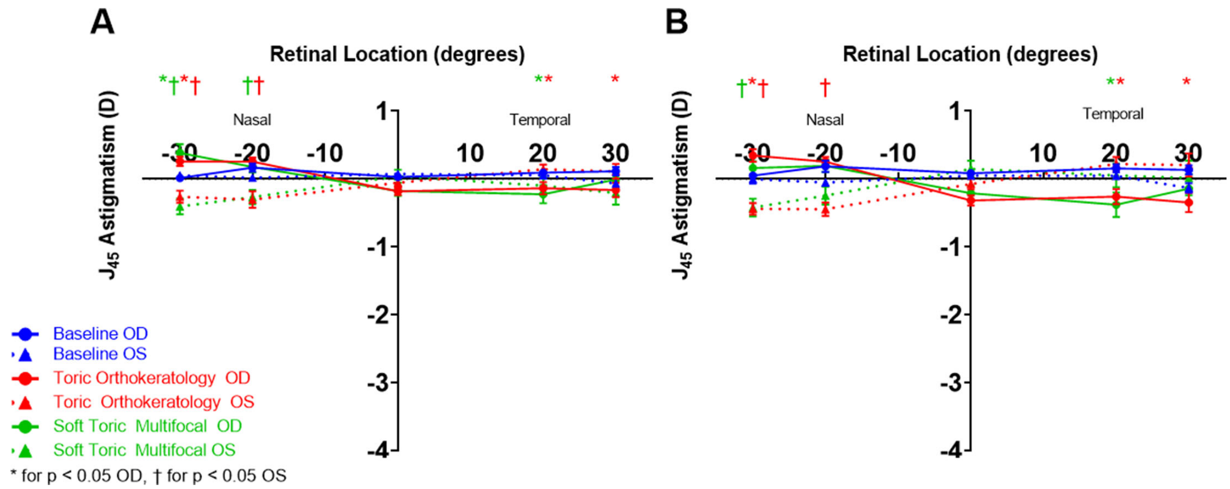

Figure 4. J_{45} astigmatism for the full sample (**A**) and good vision cohort (**B**) showing baseline (*blue*), toric orthokeratology (TOK, *red*), and soft toric multifocal (STM, *green*) conditions for the right (*solid line*) and left (*dashed line*) eyes. * Indicates $P < 0.05$ for the right eye. † Indicates $P < 0.05$ for the left eye when compared to baseline, and appear *gray* when comparing both lens types. Error bars represent standard error of the mean.

in both eyes, 20 degrees temporal in the right eye, and 20 degrees nasal in the left eye (Fig. 4A, all $P < 0.05$). STM differed from baseline for the good vision cohort at 30 degrees nasal for the left eye and 20 degrees temporal for the right eye (Fig. 4B, both $P < 0.04$). TOK differed from baseline at 30 degrees nasal in both eyes, 20 degrees and 30 degrees temporal in the right eye, and 20 degrees nasal in the left eye for both the full sample and good vision cohort (see Fig. 4, all $P < 0.05$). The two lens treatments did not differ from each other in terms of J_{45} astigmatism for either group (see Fig. 4).

Discussion

Moderate to high astigmatic eyes were able to achieve refractive correction with both toric lens modalities used for myopia management. Empirical fitting was successful in 63% and 95% of eyes with TOK and STM, respectively. One orthokeratology manufacturer claims an 87% first lens success rating with their empirical fitting.[24]

For completeness and alignment with our previous work, data from both the full sample of 30 participants and the good vision cohort of 17 participants were included. As expected, the magnitude of defocus shifts slightly, depending on the population, but the outcome is the same in that TOK lenses, at multiple retinal locations, provided more myopic defocus than STM. The same good vision cohort was also previously shown to have increased higher-order root mean square, primary spherical aberration, and primary coma root mean square with TOK compared to STM.[12]

The full sample included the good vision cohort, as well as subjects who did not achieve acceptable vision and potentially had greater lens rotation, decentered treatment zones, or inadequate treatment. The comparison of the full sample to the good vision cohort shows that on average, the full

Table 2. Changes in Peripheral Refraction With Orthokeratology

Author [Year]	Instrument/Subjects	Lens	Myopic Defocus	J_0 Astigmatism	J_{45} Astigmatism
Queirós [2010][25]	WAM-5500/28 adults	CRT	N/T: −2.00	N: −1.50 T: −2.00	N: 0.00 T: −0.25
Kang [2011][26]	Nvision-K5001/16 children	BE or BE-A lens	N: +0.25 T: −1.50	N: −1.50 T: −2.00	N: +0.25 T: 0.00
Kang [2013][27]	NVision-K5001/19 adults	BE lens	N: −0.50 T: −3.00	N: −1.25 T: −2.50	N: −0.30 T: +0.30
Kang [2016][28]	NVision-K5001/19 adults	BE lens	N: −1.25 T: −2.25	N: −1.25 T: −2.25	N: 0.00 T: +0.25
Gifford [2020][29]	SRW-5000/8 adults	Contex E	N: 0.00 T: −1.00	N: −1.00 T: −1.50	N: +0.40 T: 0.00
Ticak [2013][30]	WR-5100K/14 adults cyclopleged	CRT	N: −1.25 T: −2.00	N/A	N/A
Tomiyama [2022]	WAM-5500/17 adults cyclopleged	CRT Dual Axis	N: −1.96 T: −2.10	N: −1.64 T: −2.39	N: +0.11 T: +0.09

N/A = not applicable (was not evaluated).

All are estimations based on figures published in each paper. Measurements are at 30 degrees along horizontal retina in the nasal (N) or temporal (T) direction.

Table 3. Changes in Peripheral Refraction With Soft Multifocal Contact Lenses

Author [Year]	Instrument/Subjects	Lens	Myopic Defocus	J_0 astigmatism	J_{45} Astigmatism
Ticak [2013][30]	WR-5100K/14 adults cyclopleged*	Proclear MF D +2.00	N: +1.00 T: +0.50	N/A	N/A
Berntsen [2013][31]	WAM-5500/25 adults cyclopleged	Biofinity MF D +2.50	N: −0.75 T: −1.00	N: −0.75 T: −1.50	N: −0.10 T: 0.00
Kang [2013][32]	NVision-K5001/34 adults	Proclear MF D +2.00	N: +0.50 T: +0.50	N: −0.75 T: −1.25	N: +0.10 T: +0.30
Lopes-Ferreira [2013][33]	WAM-5500/28 adults*	Proclear MF D +2.00	N: −0.61 T: −0.94	N: −0.67 T: −1.30	N: 0.00 T: −0.09
Tomiyama [2022]	WAM-5500/17 adults cyclopleged	Proclear Toric MF D +2.50	N: −0.19 T: −0.28	N: −0.77 T: −1.35	N: +0.06 T: −0.04

* Eye was rotated for peripheral measures.
N/A = not applicable (was not evaluated).
All values are based on published figures, except Lopes-Ferreira, because raw data was not available. Measurements are at 30 degrees along horizontal retina in the nasal (N) or temporal (T) direction.

sample, which included inadequate lens fits, achieved less myopic defocus, despite having more initial myopia. The over-refraction that was added to each retinal location for each lens type corrected central refractive error but did not add any additional plus power in the periphery. Therefore, the good vision group likely had centered and well-fitting lenses that provided better correction and created more mid-peripheral steepening that provides myopic defocus.

Previous studies have evaluated changes in the peripheral refraction with non-toric orthokeratology lens designs (Table 2) and spherical soft multifocal contact lenses (Table 3). This was the first study we are aware of to demonstrate changes in peripheral defocus induced by TOK and STM corrections. To compare across studies, both Tables 2 and 3 show the relative peripheral refraction, which is the amount of peripheral defocus present if the central refractive error was fully corrected with a correction that has a perfectly spherical power profile (i.e. does not alter peripheral refraction). As demonstrated with their spherical counterparts, both toric orthokeratology and soft toric multifocal lenses increased the amount of myopic defocus. The change in myopic defocus with TOK when averaged across both eyes at the 30 degrees retinal location was generally greater than with non-toric orthokeratology lenses. The changes with STM were similar to those found in two separate studies conducted by Berntsen and Kramer and by Lopes-Ferreira et al. using rotationally symmetric center-distance soft multifocal contact lens designs.[31,33]

No other study has looked at peripheral refraction changes in patients with higher astigmatism, specifically those with at least 1.25 D of astigmatism. However, the changes in J_0 astigmatism agree with findings from previous studies of non-toric orthokeratology and soft multifocal lenses. This result suggests that peripheral astigmatism with correction is similar between high and low astigmats. The changes in J_{45} oblique astigmatism were all minimal and not clinically significant.

Only one previous study compared peripheral refraction in the same group of wearers fitted with orthokeratology and soft bifocal lenses.[30] Ticak and Walline examined 14 adult subjects but limited participants to those who had less than 0.75 D of refractive astigmatism. They found that only orthokeratology lenses induced significant peripheral myopic defocus and there was no significant change in defocus with bifocal contact lenses. In their study, subjects turned their eyes, not their head, to look at targets for peripheral refraction. The authors suggested that decentration of the soft lens opposite to the subject's direction of gaze may have caused measurements that did not accurately capture the peripheral add portion of the bifocal lens, thus decreasing the measured myopic defocus induced by the bifocal lenses that has been reported in other studies.

In the current study, which compared the toric versions of these two lens types, we found significant myopic defocus induced by TOK at all peripheral locations; whereas the defocus induced by STM was significantly different than baseline at fewer retinal locations. Comparing the two lens modalities to each other, there were greater amounts of peripheral myopic defocus with TOK, specifically at the 30 degrees locations. If the predominantly hypothesized mechanism for why multifocal lenses slow myopia progression is correct (i.e. more myopic defocus is better for slowing eye growth), then our finding could mean that TOK would be more effective for myopia management, at least for patients with moderate myopia (2–3 D). This is in agreement with previous analyses which suggested that lower myopes may achieve more myopic defocus with a multifocal contact lens (with adds of 2 D or higher), while higher myopes may achieve more with orthokeratology (due to higher corneal defocus).[25,34]

There was an increase in peripheral astigmatism, primarily J_0 astigmatism, with TOK, but not STM. One reason for this increase with TOK could be that the autorefractor measured across two zones (the central distance or treatment zone and the peripheral plus from the STM add or TOK midperipheral ring of corneal steepening) when measuring off-axis.[19] For TOK, the average treatment zone measured from corneal tomography was 3.3 mm, whereas the manufacturer defined central spherical zone of the STM lens was 2.3 mm.

Further studies are needed to show these defocus changes exist in children. The current study was performed with adult subjects to gather more accurate data as part of a larger study comparing TOK and STM lenses.[12] Although the sample size was small, it was within the range of previous studies that included 14 to 35 subjects. Additionally, the outcomes were statistically significant and clinically meaningful, so a larger study is not warranted for this age and refractive group. Future studies could expand on the refractive range for both myopia and astigmatism. Another limitation to this study was that the subjects were not refit in either lens modality to attempt to improve fit or vision after the initial empirically ordered lens. Whereas some participants had a moderate amount of lens rotation, the good vision cohort still achieved acceptable visual acuity, so a refitting was not warranted. Three of 60 eyes were excluded from the good vision cohort due to poor vision with STM; however, the major outcomes of peripheral refraction were similar. There is no standardized protocol for refitting TOK lenses and no accepted end point for modifications based on topography, refraction, and visual acuity. Patients often have slightly decentered lenses and visual acuity worse than 20/20 but are clinically acceptable. This allowed us to evaluate the success rate of empirical fitting with both lens modalities. A future study could aim to achieve acceptable vision in a larger cohort of children with a wider range of refractive error and follow them longitudinally to explore efficacy differences between TOK and STM lenses.

Conclusion

Empirical order of STM and TOK in myopic astigmatic patients led to higher initial success rates for STM. In adults fitted with both TOK and STM contact lenses, greater myopic defocus was induced by toric orthokeratology. For patients with astigmatism requiring toric correction, STM may be more expedient to fit, but TOK may be more effective in slowing myopia progression. Larger longitudinal studies in children are needed to confirm this hypothesis.

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